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Belet

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(54) **METHOD FOR POWERING A MODULE INCORPORATED WITHIN A SYSTEM-ON-A-CHIP AND CORRESPONDING ELECTRONIC DEVICE**

(58) **Field of Classification Search**
CPC G05F 1/46
USPC 327/538
See application file for complete search history.

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(56) **References Cited**

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U.S. PATENT DOCUMENTS

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5,671,149 A 9/1997 Brown
7,447,924 B2 * 11/2008 May G06F 1/26
713/300

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2004/0233589 A1 11/2004 Dewey
2006/0126367 A1 * 6/2006 Hesterman H02M 3/33507
363/89

2008/0315831 A1 12/2008 Li et al.
2012/0194149 A1 8/2012 Noda
2015/0028942 A1 1/2015 Fukuda

* cited by examiner

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(30) **Foreign Application Priority Data**

May 5, 2015 (FR) 15 53994

(57) **ABSTRACT**

A module incorporated within a system-on-a-chip operating in a steady-state power supply phase is powered by supplying to the module a regulated power supply voltage obtained from a feedback control loop. The receives a main power supply voltage and a negative feedback voltage. The negative feedback voltage is generated inside the system-on-a-chip starting from an effective supply voltage of the module and from a setpoint signal corresponding to a desired regulated power supply voltage.

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G05F 3/02 (2006.01)
G05F 1/46 (2006.01)
G06F 1/26 (2006.01)

30 Claims, 6 Drawing Sheets

(52) **U.S. Cl.**

CPC . **G05F 1/46** (2013.01); **G06F 1/26** (2013.01)

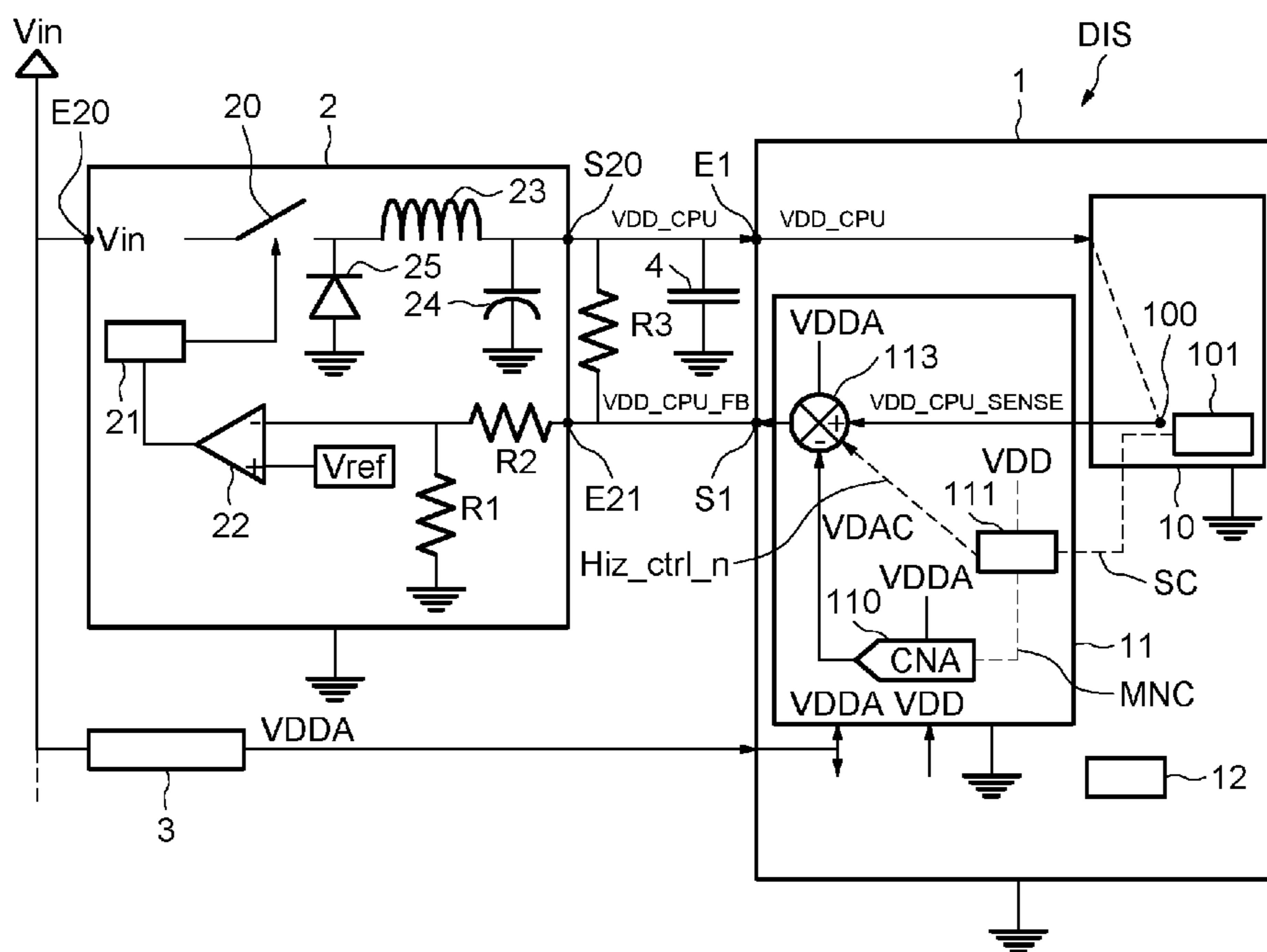


FIG. 1

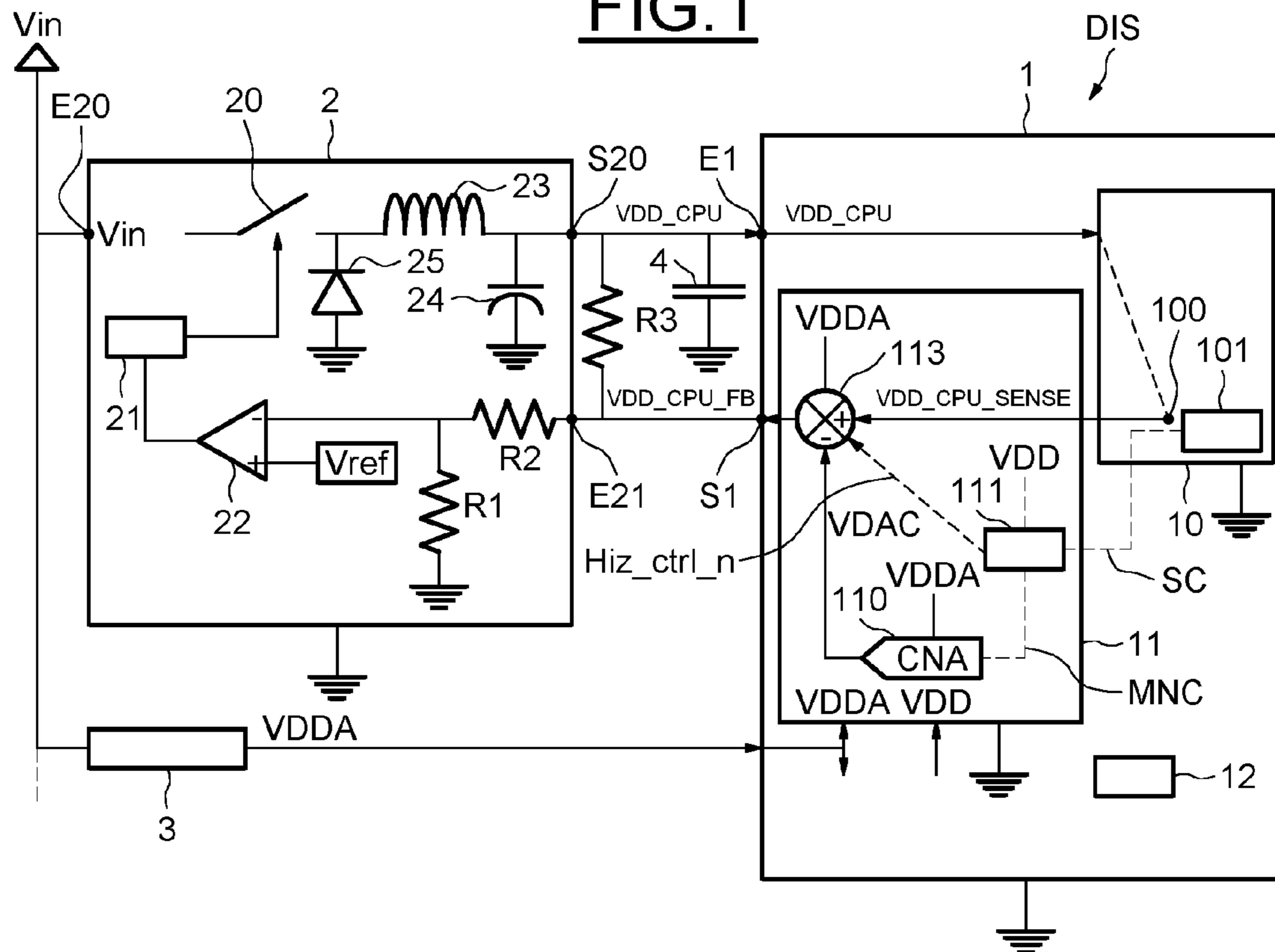


FIG. 2

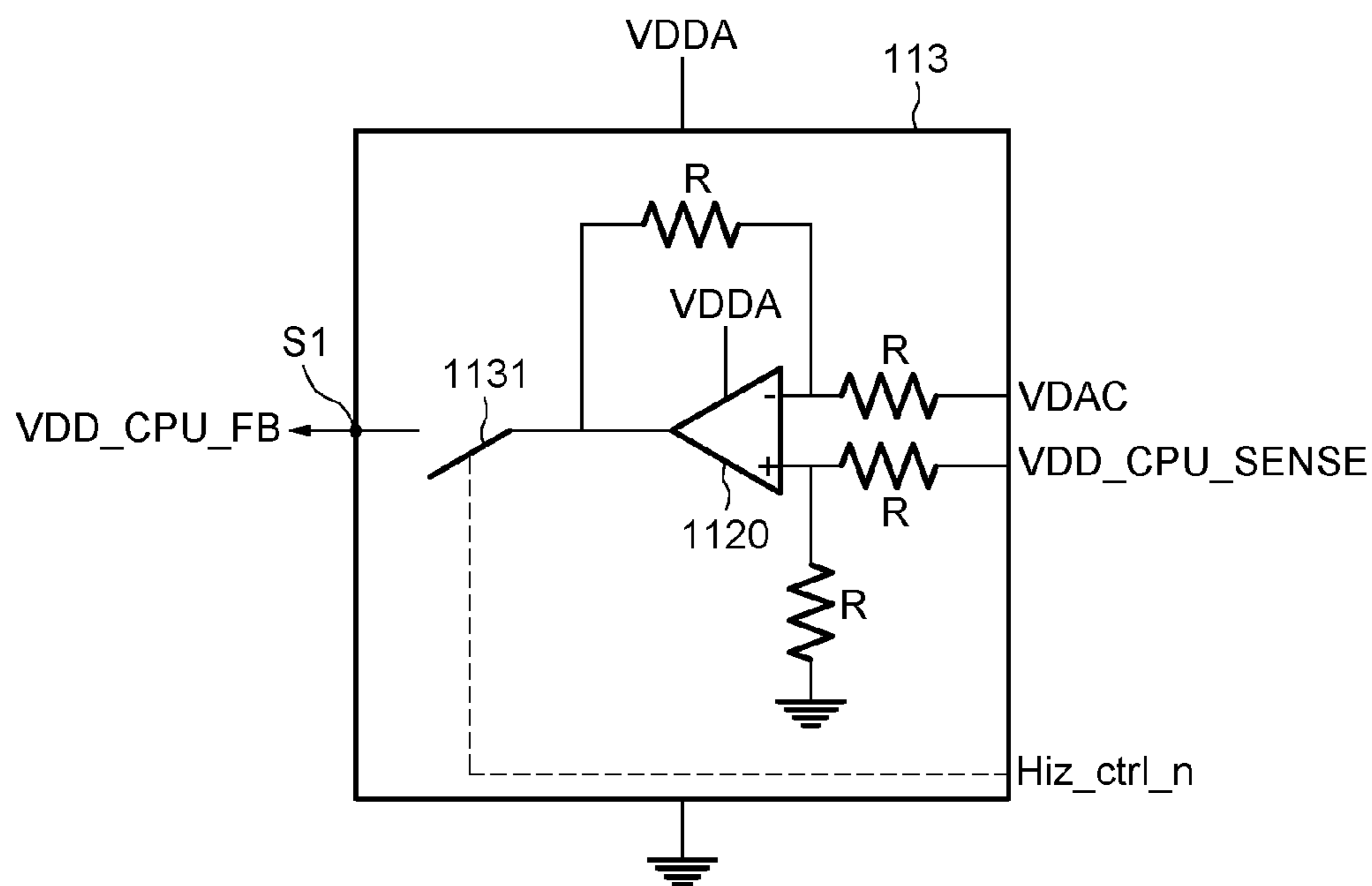


FIG. 3

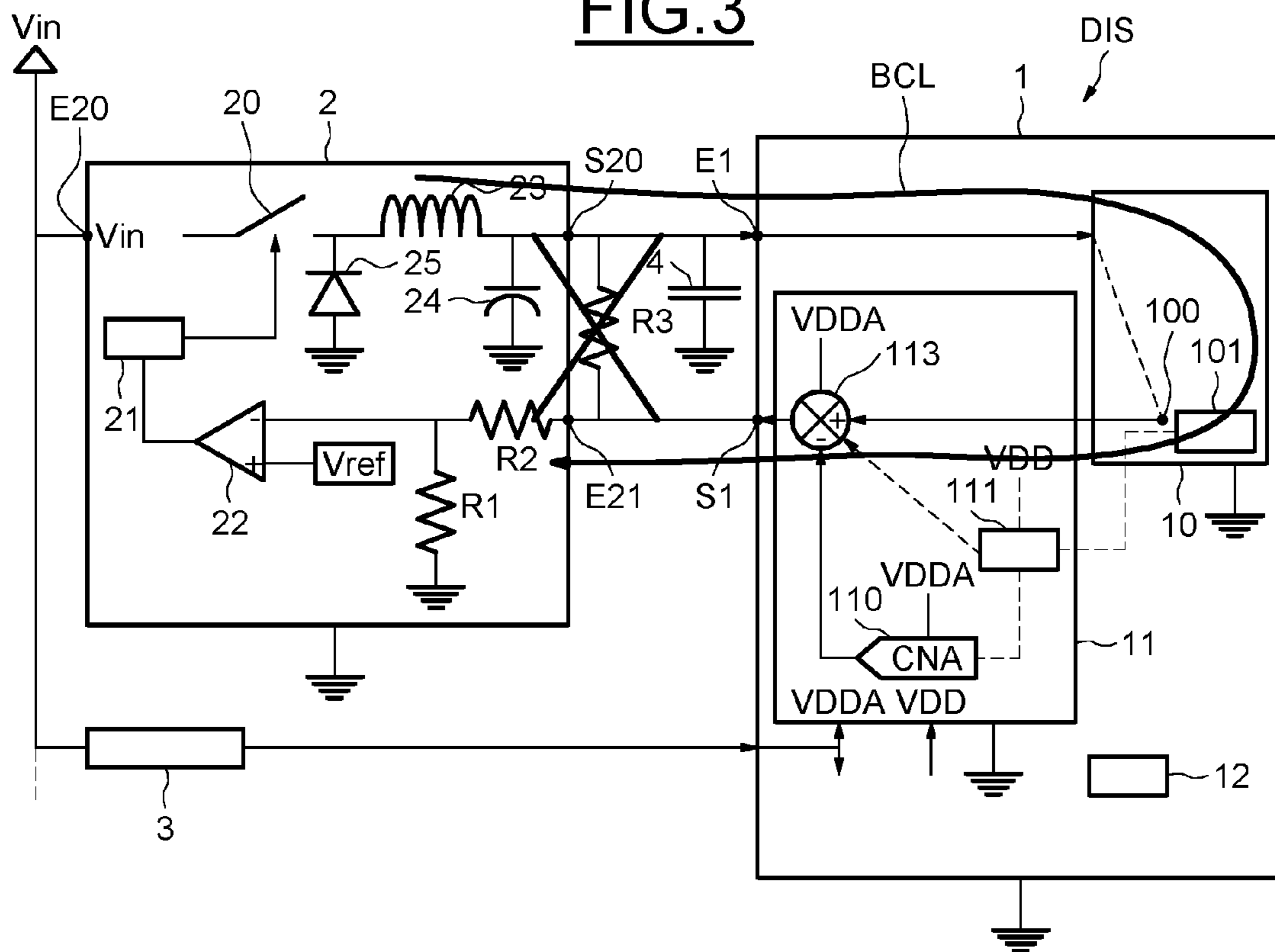


FIG. 4

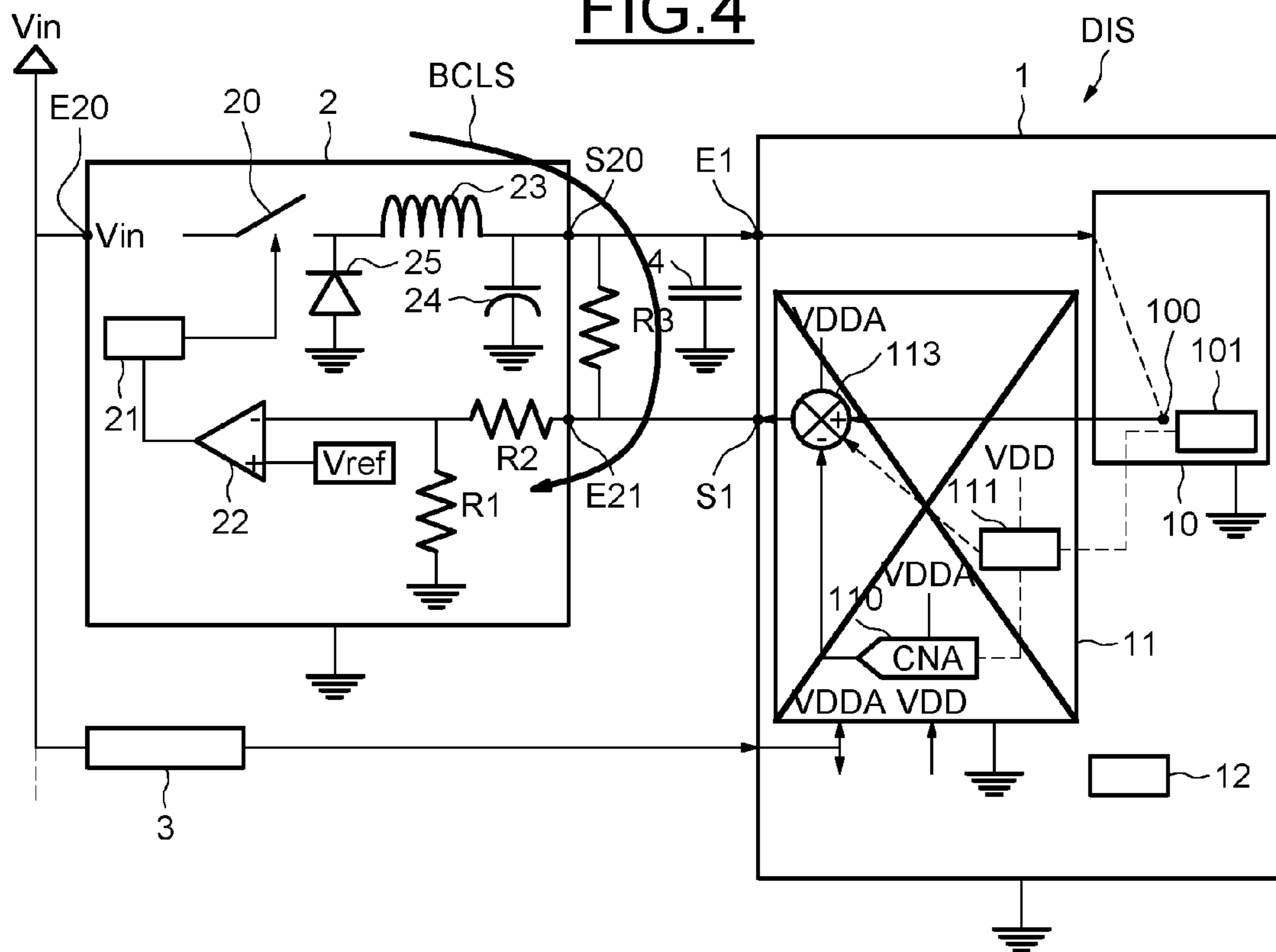


FIG. 5

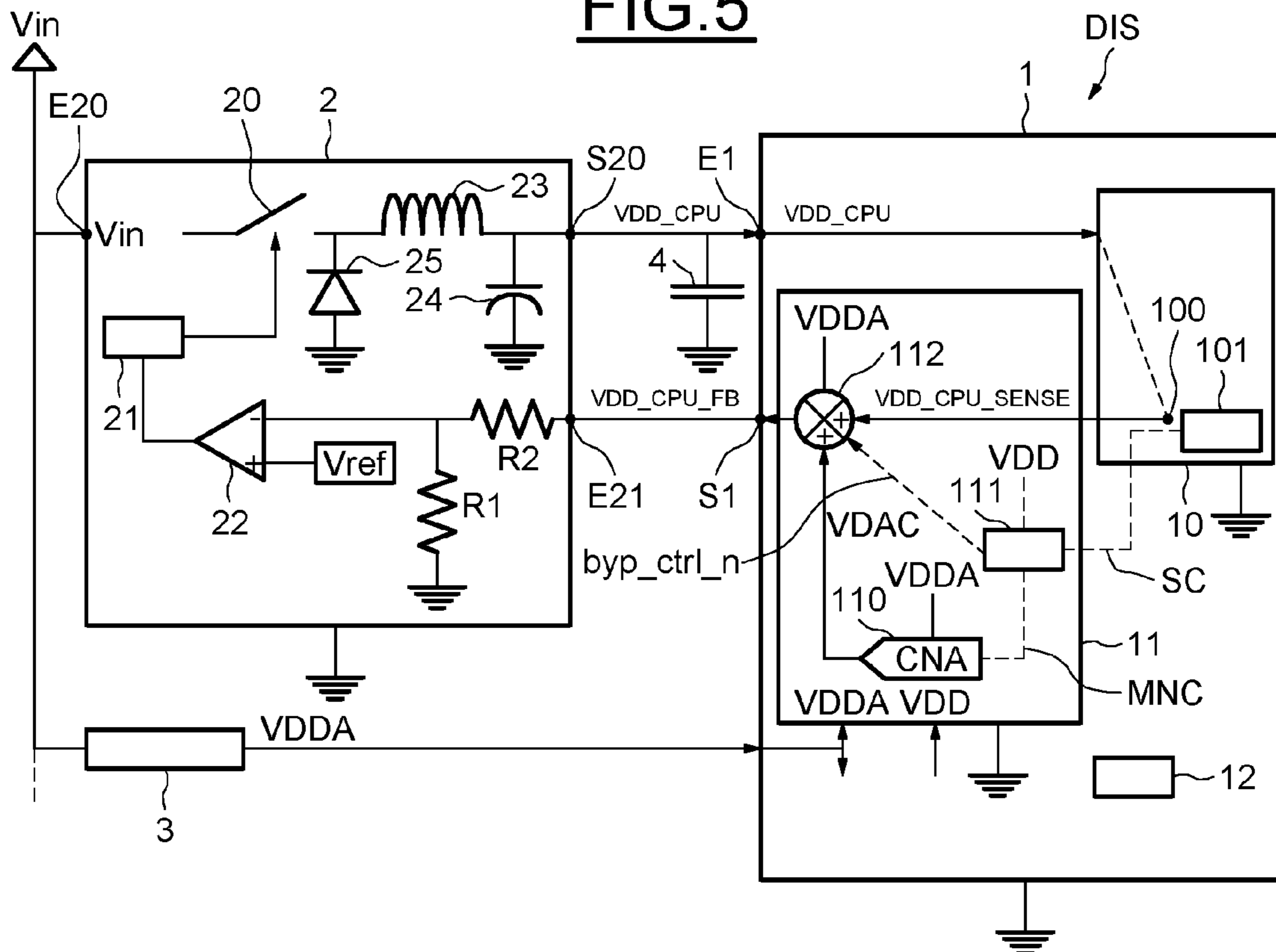


FIG. 6

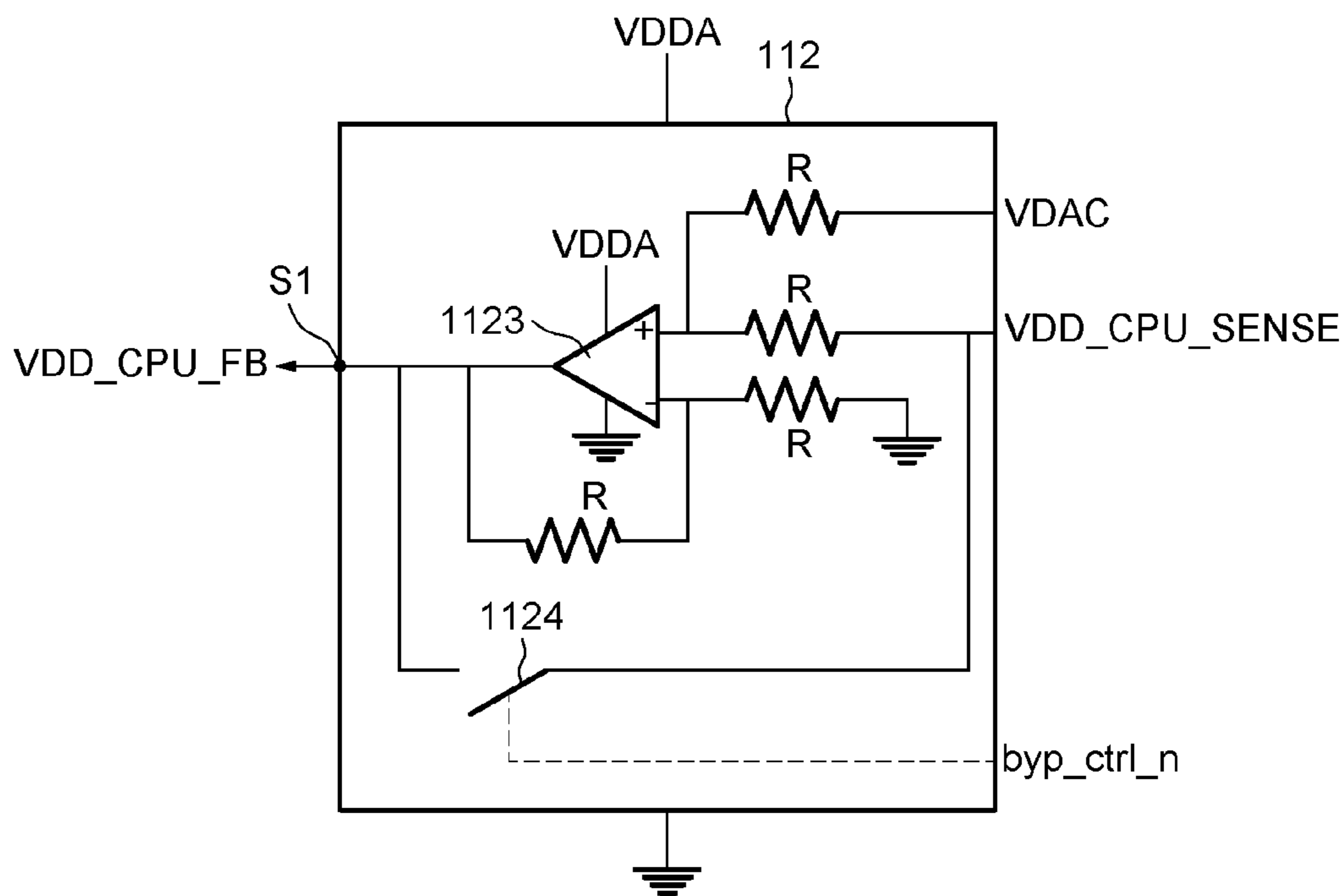


FIG. 7

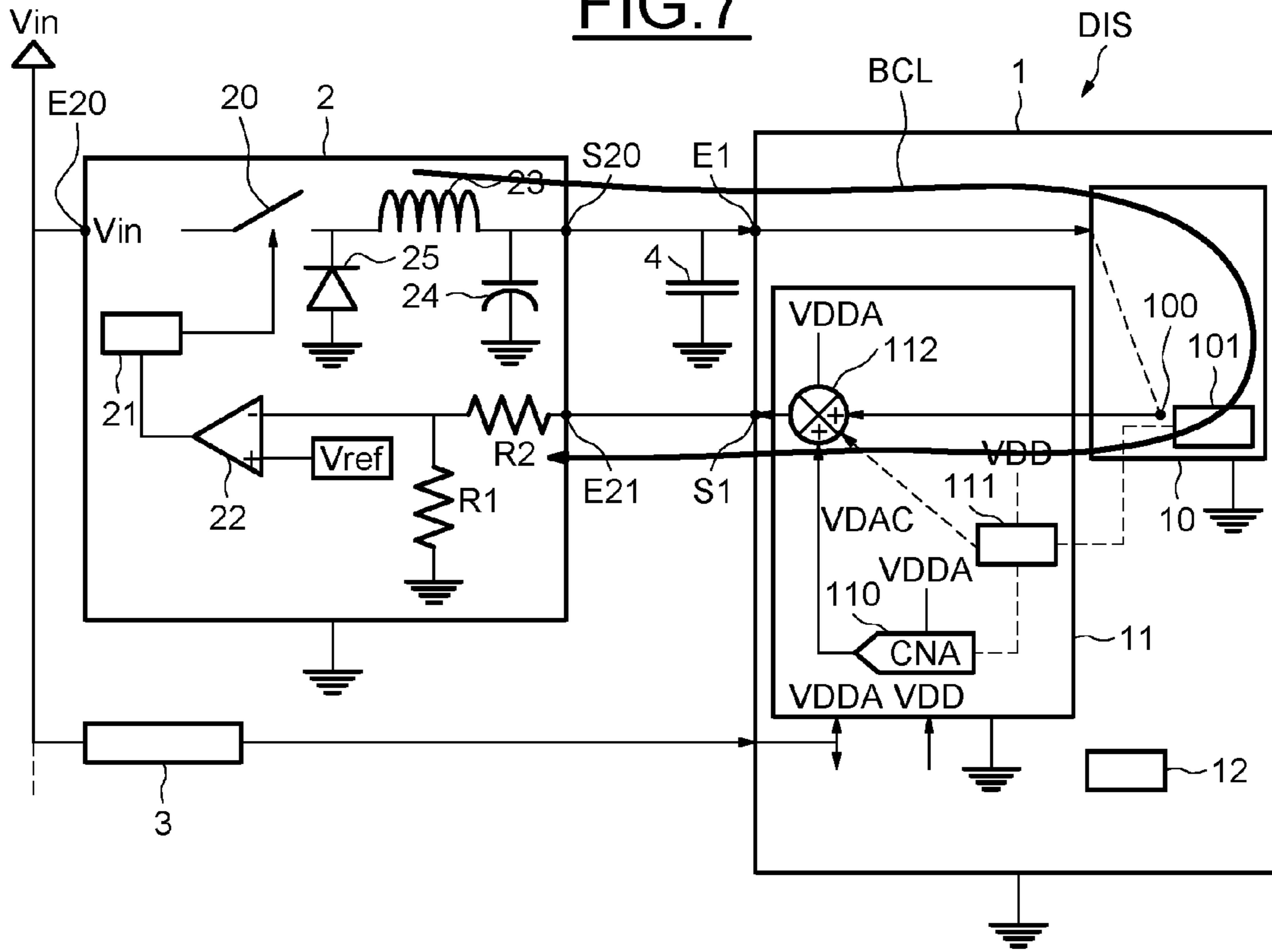


FIG. 8

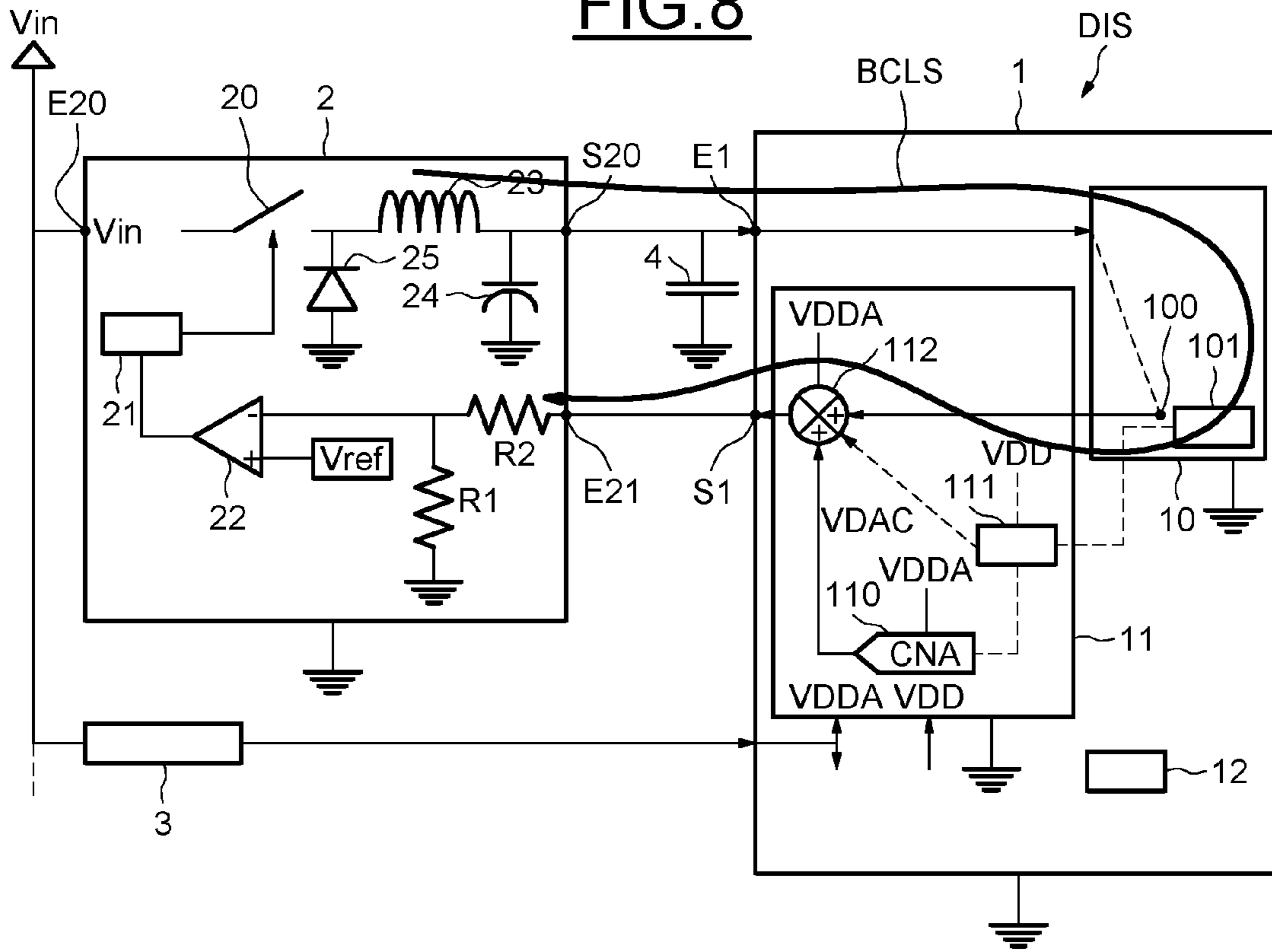


FIG. 9

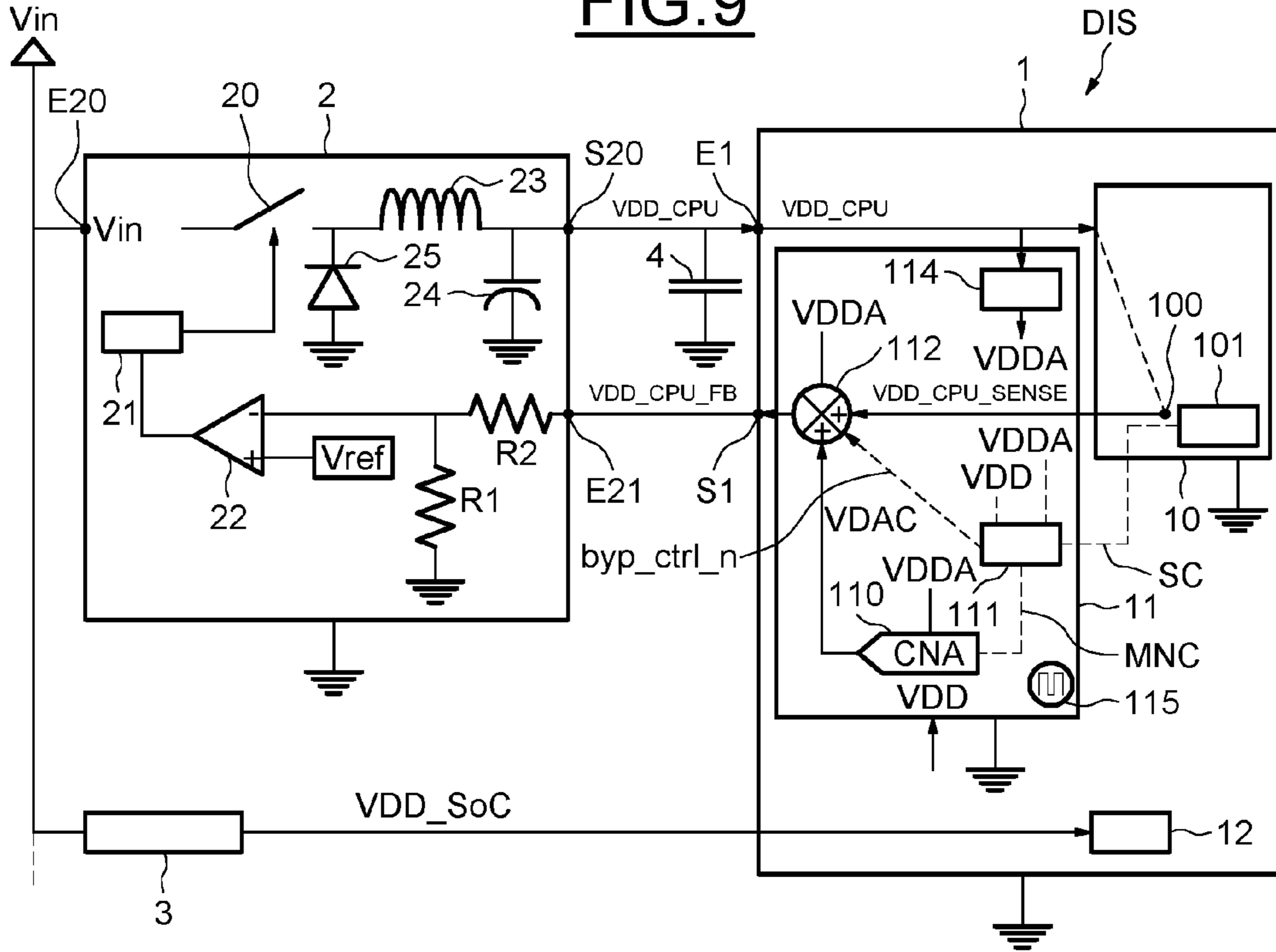


FIG. 10

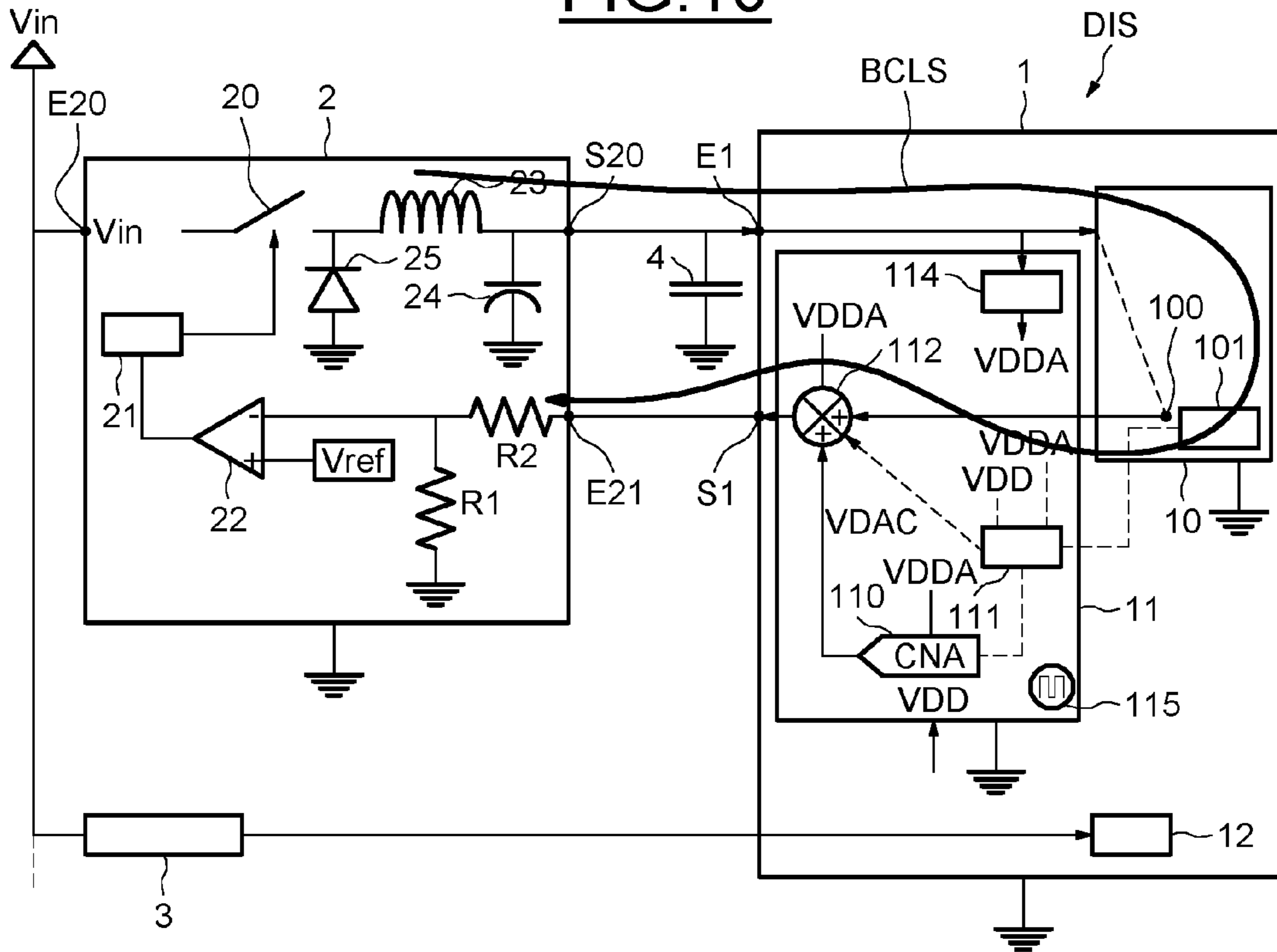
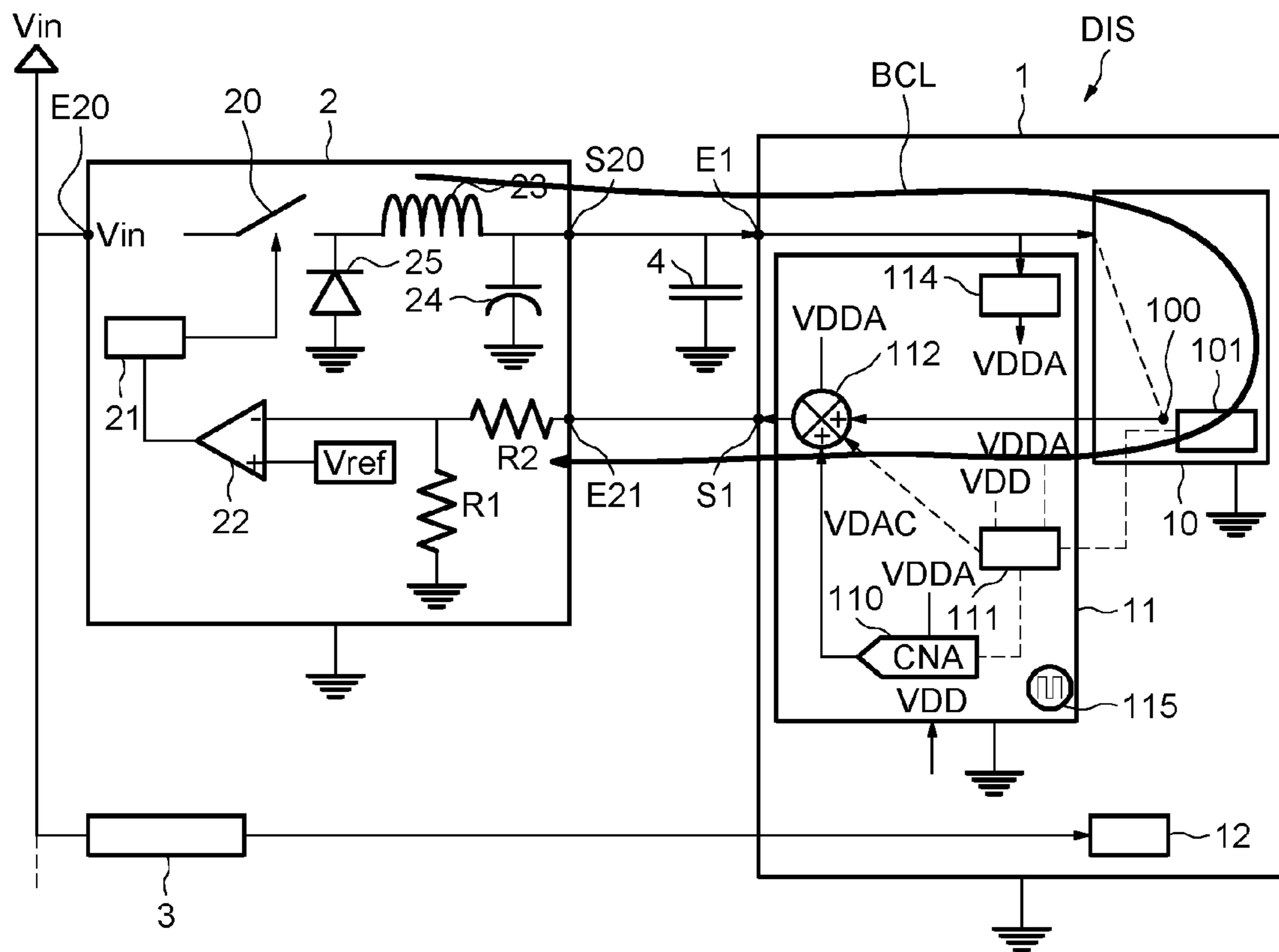


FIG. 11



**METHOD FOR POWERING A MODULE
INCORPORATED WITHIN A
SYSTEM-ON-A-CHIP AND
CORRESPONDING ELECTRONIC DEVICE**

PRIORITY CLAIM

This application claims priority from French Application for Patent No. 1553994 filed May 5, 2015, the disclosure of which is incorporated by reference.

TECHNICAL FIELD

Various embodiments relate to electrical circuits and, notably, the management of the power supply for a system-on-a-chip (known as an 'SoC') with the purpose of simplifying the control of the adaptive voltage scaling (or AVS) and of improving the response time of the dynamic voltage and frequency scaling (or DVFS).

BACKGROUND

Currently, numerous electronic devices, such as cellular mobile telephones, tablets, decoders, etc., and more generally onboard devices, have power saving modes which allow the power consumption to be reduced and the heat dissipation to be limited.

Conventionally, the power distribution networks (or PDN) for electronic devices comprise a set of switching regulators and/or a power management unit (or PMU). This allows the power supply to the various areas of the system-on-a-chip to be distributed efficiently.

Furthermore, in such a manner as to increase the precision of voltage regulation for sensitive electronic devices such as systems-on-a-chip, the idea is to provide closed-loop control for the voltage regulator with a negative feedback voltage coming from inside the device, for example that taken from the power grid. This allows the voltage losses, due notably to the printed circuit board (or PCB) onto which the system-on-a-chip is mounted and to the packaging, to be compensated.

Generally speaking, a system-on-a-chip, notably when it incorporates a central processing unit (or CPU), is the assembly with the highest power consumption within a product and modes dedicated to power saving are provided.

The methods used most commonly for implementing these power saving modes are adaptive voltage scaling (or AVS) and dynamic voltage and frequency scaling (or DVFS) which are both aimed at adapting the various power supply voltages of the various parts of the system-on-a-chip to their lowest possible values taking into account the state of the system-on-a-chip.

More precisely, a desired value of regulated power supply voltage is determined by the system-on-a-chip as a function of a set of criteria such as the frequency of the clock signal supplying the central processing unit, the temperature, the variations of certain parameters due to the process of fabrication on silicon, etc.

This desired regulated power supply voltage is subsequently used in the feedback control loop.

For this purpose, dedicated circuits for carrying out the voltage adaptation are used.

Amongst these circuits may notably be mentioned those, for example, incorporated into portable devices such as mobile telephones, tablets, whose architecture contains a power management unit (PMU) containing a control interface connected to a homologous control interface of the

system-on-a-chip via a specific bus, for example an SPI or I²C bus, together with regulators. Programmable regulators may also be used.

However, such an architecture proves to be costly and it requires a dedicated interface for the control bus which can occupy several input/output terminals of the system-on-a-chip.

A second type of possible architecture includes the use of a module delivering pulses with a modulated width (pulse width modulation: PWM) associated with a low-pass filter in such a manner as to eliminate the AC modulation and to only keep the DC voltage.

However, such an architecture requires a suitable design and the implementation of a low-pass filter external to the system-on-a-chip and introduces a time delay between the moment when the desired regulated power supply voltage is calculated and the moment when the correction is applied in the regulator.

However, such a delay is not acceptable when the voltage must be dynamically adapted (DVFS).

SUMMARY

According to one embodiment and its implementation, a power supply is provided for a module incorporated within a system-on-a-chip, for example a central processing unit (CPU), without the use of pulse-width-modulated signals, nor a specific bus of the SPI or I²C type for example, and using conventional regulators, in other words non-programmable, with the same performance characteristics as those obtained with programmable regulators.

According to one aspect, a method is provided for powering a module incorporated within a system-on-a-chip, comprising a steady-state power supply phase (which follows a power-up phase) comprising the supply to the module of a regulated power supply voltage obtained from a feedback control loop receiving a main power supply voltage and a negative feedback voltage, this negative feedback voltage being generated inside the system-on-a-chip starting from an effective supply voltage of the module and from a setpoint signal corresponding to a desired regulated power supply voltage.

Thus, according to this aspect, the negative feedback voltage is generated inside the system-on-a-chip which simplifies the fabrication and notably avoids the use of a low-pass filter or of a specific bus connected to a power management unit (PMU).

According to one embodiment, the generation of the negative feedback voltage comprises a conversion of a setpoint digital word, taken from the setpoint signal, into a voltage offset analog signal.

This voltage offset analog signal can then either be summed with the effective supply voltage or else this voltage offset analog signal can be subtracted from the effective supply voltage.

The method according to this aspect furthermore comprises a power-up phase of the system-on-a-chip during which making the regulation operate in open loop mode is avoided.

Thus, according to one possible embodiment, the power-up phase comprises the placing into a high impedance of the setpoint output of the system-on-a-chip designed to deliver the negative feedback voltage in steady-state mode, and the establishment of a temporary feedback control loop using a resistor connected between the power supply input of the system-on-a-chip receiving the regulated power supply voltage and the setpoint output.

The method then advantageously comprises the placing of the output into a low impedance during the transition between the power-up phase and the steady-state power supply phase, in such a manner as to re-establish the feedback control loop going via the system-on-a-chip.

According to another possible embodiment, the power-up phase can comprise the direct delivery of the effective supply voltage to the setpoint output.

According to another aspect, an electronic device is provided, comprising: a system-on-a-chip comprising a power supply input for receiving a regulated power supply voltage, a module, for example a central processing unit (CPU), intended to be powered by the regulated power supply voltage, control means configured for generating a setpoint signal corresponding to a desired regulated power supply voltage for the module, a voltage adaptation circuit configured for generating a negative feedback voltage starting from an effective supply voltage of the module and from the setpoint signal, and a setpoint output for delivering the negative feedback voltage, and voltage regulation means having a regulation output coupled to the power supply input, a negative feedback input coupled to the setpoint output and configured for delivering the regulated power supply voltage to the regulation output starting from a main power supply voltage and from the negative feedback voltage.

According to one embodiment, the regulation means comprise a switch-mode regulator comprising a switching means, connected between a main input for receiving the main power supply voltage and the regulation output, controllable by a control signal coming from an output signal of a comparator having a first comparator input designed to be connected to a reference voltage and a second comparator input coupled to the negative feedback input via a divider bridge.

According to one variant embodiment, the voltage adaptation circuit comprises a digital-analog converter designed to deliver, in the presence of a setpoint digital word taken from the setpoint signal, a voltage offset analog signal and an adder configured for adding the voltage offset analog signal and the effective supply voltage and thus obtaining the negative feedback voltage.

According to another possible variant embodiment, the voltage adaptation circuit comprises a digital-analog converter designed to deliver, in the presence of a setpoint digital word taken from the setpoint signal, a voltage offset analog signal and a subtractor configured for subtracting the voltage offset analog signal from the effective supply voltage and thus obtaining the negative feedback voltage.

The device furthermore advantageously comprises protection means configured for avoiding, when the device is powered up, an operation of the regulation means in open loop mode.

According to one possible embodiment, the protection means comprise a resistor connected between the power supply input and the setpoint output and a controllable switch, connected between the output of the subtractor and the setpoint output, designed to be in an open state as long as the voltage adaptation circuit is not powered and in a closed state when the adaptation circuit is powered.

According to another possible embodiment, the protection means comprise a controllable switch configured for shunting the adder in such a manner as to deliver the effective supply voltage to the setpoint output as long as the voltage adaptation circuit is not powered.

The device may also furthermore comprise auto-power supply means for the voltage adaptation circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

Others advantages and features of the invention will become apparent from the detailed description of non-limiting embodiments and their implementation, and from the appended drawings in which:

FIGS. 1 to 11 illustrate schematically various embodiments and their implementation.

DETAILED DESCRIPTION

In FIG. 1, the reference DIS denotes an electronic device comprising a system-on-a-chip (SOC) 1 including, in the present case, a module 10 formed by a central processing unit (CPU).

The system-on-a-chip 1 furthermore comprises other modules which have been represented schematically under the reference 12.

The system-on-a-chip 1 comprises a power supply input E1 for receiving a regulated power supply voltage VDD_CPU intended to power the module 10.

A capacitor 4, intended for the high frequency filtering of the activity of the central processing unit, is generally connected between the input E1 and ground.

The module 10 here comprises control means 101, for example a software module executed by the CPU, configured for generating a setpoint signal SC corresponding to a desired regulated power supply voltage.

The system-on-a-chip 1 further comprises a voltage adaptation circuit 11 configured for generating a negative feedback voltage VDD_CPU_FB starting from an effective supply voltage of the module VDD_CPU_SENSE and from a voltage offset analog signal VDAC obtained, as will be seen in more detail hereinafter, by a digital-analog conversion of a setpoint digital word MNC taken from the setpoint signal SC.

For this purpose, the voltage adaptation circuit here comprises a subtractor 113 configured for subtracting the signal VDAC from the effective supply voltage of the module VDD_CPU_SENSE.

The effective supply voltage is measured inside the module 10, for example on a power grid 100.

It should, at this point, be noted here that the effective supply voltage VDD_CPU_SENSE will eventually be the desired regulated power supply voltage after processing in regulation means 2, the structure of which will be described in more detail hereinafter.

The signal VDAC is a DC voltage offset obtained, as indicated hereinbefore, by a digital-analog conversion of the setpoint word MNC delivered by a control block 111, in a digital-analog converter (CNA) 110.

The control block is formed, for example, by a logic circuit.

The voltage range of the digital-analog converter 110 is equal to $(VDD_CPU_max - VDD_CPU_min)$ where VDD_CPU_min is the minimum voltage that can be applied to the module 10 and VDD_CPU_max is the maximum voltage that can be applied to the module 10.

The increment in voltage (or 'voltage step') depends on the granularity required for the voltage adaptation.

In this embodiment, the converter 110 is powered by the positive voltage VDDA.

As a consequence, the output of the converter 110 produces a positive voltage which obviates the need for the addition of a negative voltage able to be generated by a switch-mode regulator of the negative charge pump type.

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The regulation means **2** here comprise a non-programmable switch-mode regulator circuit, in this case a voltage step-down switch-mode regulator.

The switch-mode regulator **2** comprises, for this purpose, a switch controllable by a control logic **21** receiving the output signal from an error amplifier or comparator **22**.

The non-inverting input of the error amplifier **22** is connected to a source of reference voltage V_{ref} and the inverting input is connected to a negative feedback input **E21** of the regulation means **2** via a divider bridge **R1**, **R2**. The negative feedback input **E21** is connected to the setpoint output **S1** and will therefore receive the negative feedback voltage VDD_CPU_FB .

A first terminal of the switch **20** is connected to a power supply main input **E20** designed to receive a main power supply voltage V_{in} . The other terminal of the switch **20** is connected to the regulation output **S20** of the regulation means **2** via a diode **25**, an inductor **23** and a capacitor **24**.

It will be noted here that, even if the divider bridge **R1**, **R2**, the inductor **23**, the capacitor **24** and the diode **25** do not form part of the switch-mode regulator per se, they are nevertheless considered here as forming part of the regulation means **2** in the wider sense of the term.

The regulation output **S20** delivers the regulated power supply voltage VDD_CPU .

Furthermore, a resistor **R3**, whose function will be considered in more detail hereinafter, is connected between the input **E1** and the output **S1** of the system-on-a-chip **1**.

In the example described here, another regulator **3** delivers, starting from the main power supply voltage V_{in} , a voltage $VDDA$ intended to supply the analog part of the system-on-a-chip **1**, and notably certain elements of the voltage adaptation circuit **11**.

Lastly, a power supply voltage VDD designed to supply the control block **111** generating the setpoint word **MNC** originates from an internal power supply of the system-on-a-chip or from an external power supply, for example another regulator of the type of the regulator **3**.

The control block **111** is also configured for delivering a control signal Hiz_CTRL_n so as to control a switch connected to the output of the subtractor **113**.

If reference is now more particularly made to FIG. **2**, it can be seen that the subtractor **113** here comprises a differential amplifier **1120** whose inverting input receives the signal $VDAC$ via a resistor **R** and whose non-inverting input receives the signal VDD_CPU_SENSE via another resistance **R**.

The amplifier **1120** is powered by the voltage $VDDA$ and the output of the amplifier **1120** is connected to the setpoint output **S1** via the switch **1131** controlled by the signal Hiz_CTRL_n .

As a result, when the switch **1131** is open, the setpoint output **S1** is at a high impedance, whereas when the switch is closed, the output **S1** is at a low impedance.

Reference is now more particularly made to FIG. **3** in order to illustrate the voltage regulation in power supply steady-state mode.

As indicated hereinbefore, the regulation means **2** deliver the regulated power supply voltage VDD_CPU to the input **E1** of the system-on-a-chip **1**.

The voltage VDD_CPU_FB is defined by the equation (1) hereinbelow:

$$VDD_CPU_FB = VDD_CPU_SENSE - VDAC \quad (1)$$

in which the voltage VCC_CPU_SENSE represents both the effective supply voltage of the module **100** but also the new

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desired regulated power supply voltage (after passing through the feedback control loop).

Furthermore, the voltage VDD_CPU_FB is defined by the equation (2) hereinbelow:

$$VDD_CPU_FB = (R1 + R2)V_{ref}/R1 \quad (2)$$

From the equations (1) and (2) hereinabove, it can be seen that the voltages VDD_CPU_SENSE and $VDAC$ are mutually connected by the equation (3) hereinbelow:

$$VDD_CPU_SENSE = VDAC + (R1 + R2)V_{ref}/R1 \quad (3)$$

Furthermore, the resistors **R1** and **R2** of the divider bridge are calculated in such a manner that the equation (4) hereinbelow is satisfied:

$$VDD_CPU_SENSE = VDD_CPU_min + VDAC \quad (4)$$

It should be noted here that, as illustrated in FIG. **3**, the resistor **R3** may be ignored because the output **S1** is at a low impedance (switch **1131** closed).

Accordingly, the voltage adaptation, illustrated by the loop **BCL** in FIG. **3**, operates in the following manner.

When there is a request for a change of power supply voltage (for example a new DVFS point of operation), the control means **101** determine a new desired power supply voltage VDD_CPU_SENSE .

The control means **101** therefore send the setpoint signal **SC** corresponding to this new desired regulated power supply voltage to the control block **111** which generates the setpoint word **NMC** in such a manner that the offset signal $VDAC$ satisfies the equation (3) hereinbefore.

The digital-analog converter **110** performs this conversion over a certain period of time.

The signal $VDAC$ is delivered to the subtractor **113** which delivers the negative feedback voltage VDD_CPU_FB at its output, which satisfies the equation (1) hereinbefore.

The regulation means **2** then regulate the voltage at the output **S20** such that the regulated voltage VDD_CPU reaches the new desired regulated power supply voltage VDD_CPU_SENSE .

The new desired regulated voltage thus obtained VDD_CPU_SENSE then becomes the effective supply voltage present on the power grid **100** of the module **10**.

The transition between the sending of the setpoint signal **SC** and the obtaining of the new desired regulated power supply voltage is very fast and mainly depends on:

- the conversion time, which naturally depends on the design of the digital-analog converter, but which is typically of the order of a few microseconds, and
- the response time of the regulation means, which depends on the bandwidth itself linked to the performance of the regulator, but which is also typically of the order of a few microseconds.

During the power-up phase, under the assumption that the voltage adaptation circuit **11** is first to be powered up, for example by the regulator **3**, then there is no need to take any particular precautions.

However, in order to avoid any design constraints, the device **DIS** is designed in such a manner that the various power-up phases of the various components of this device may be carried out in any given order.

In this case, it is advantageous to provide protection means configured for avoiding an operation of the regulation means in open loop mode during the power-up phase.

Indeed, if it is assumed that the regulation means **2** are the first to start up and that the voltage VDD_CPU is established before other regulators start up, such as the regulator **3** which provides the power supply voltage $VDDA$ for the

voltage adaptation circuit **11**, then the voltage VDD_CPU would not be regulated and could increase up to the voltage Vin causing the immediate destruction of the module **10**. Indeed, the voltage Vin can be around 5 volts, whereas the regulated power supply voltage VDD_CPU admissible for the module **10** may be limited to 1 volt for example.

Also, in this embodiment, as illustrated in FIG. 4, during the power-up phase, the resistor R3 allows a temporary feedback control loop BCLS to be formed.

The value of the resistor R3 is chosen in such a manner that the regulated voltage VDD_CPU is higher than the voltage VDD_CPU_min so as to guarantee a correct initialization of the system-on-a-chip, since the voltage losses across the printed circuit board (PCB), the packaging of the system-on-a-chip and the power grid are not compensated until the voltage adaptation circuit **11** is in operation.

Also, during this power-up phase, in order for the resistor R3 to allow the feedback of the regulation means, the setpoint output S1 is placed at a high impedance (switch **1131** open).

Thus, during this power-up phase and until the operation of the voltage adaptation circuit **11**, reset by the module **10**, the regulated power supply voltage provided at the output S20 is equal to VDD_CPU_pu and is defined by the equation 5 hereinbelow:

$$VDD_CPU_pu=(R1+R2+R3)Vref/R1 \quad (5)$$

The power-up sequence is then as follows.

It is assumed that, initially, no power supply voltage is present.

The power supply voltage Vin is available for example from a charger connected to a device, for example a cellular mobile telephone, incorporating the device DIS.

All the regulators of the device start up in no particular order and their respective regulated output voltage is established.

When the regulation means **2** start up and the power supply voltage delivered at the output S20 is established, this voltage is regulated by the temporary loop BCLS so as to take the value VDD_CPU_pu defined by the equation (5) hereinabove.

Then, when all the regulators of the device have delivered their regulated power supply voltage and the reset pin of the system-on-a-chip is disabled, the power supply voltages VDD and VDDA of the voltage adaptation circuit **11** are available.

During the boot-up sequence of the system-on-a-chip, the control means **101** reset the voltage adaptation circuit **11** by sending the setpoint signal SC to the control block **111** so as to reset and send a command to the digital-analog converter **110** to eventually produce the desired regulated power supply voltage.

Furthermore, the control block **111** closes the switch **1131** which places the output S1 at a low impedance.

From this point on, the value of the resistor R3 becomes negligible relative to the value of the output impedance of the differential amplifier **1120**.

Then, the regulation sequence can then be carried out as described hereinbefore with reference to FIG. 3.

Reference is now more particularly made to FIGS. 5 to 8 in order to illustrate another embodiment of the device DIS.

The embodiment in FIG. 5 differs from that in FIG. 1 by the fact that the subtractor **113** is replaced here by an adder **112** receiving, on the one hand, the effective supply voltage VDD_CPU_SENSE and, on the other hand, the analog voltage offset signal VDAC. Furthermore, the resistor R3,

which was an element of the protection means, external to the system-on-a-chip, is eliminated.

As illustrated more precisely in FIG. 6, the adder **112** here comprises an operational amplifier **1123** configured as an adder and receiving on its non-inverting input the voltages VDAC and VDD_CPU_SENSE via two resistors R.

Furthermore, a switch **1124** is connected between the input of the adder receiving the voltage VDD_CPU_SENSE and the output of the operational amplifier **1023**. This switch **1124** is controlled by a signal byp_crtl_n delivered by the control block **111**.

Thus, when the switch **1124** is in the closed position, it acts as a “by-pass” and the voltage VDD_CPU_SENSE is delivered directly to the output of the adder **112** (setpoint output S1).

In view of the fact that the adder **112** replaces the subtractor **113**, the equations (1), (3) and (4) hereinbefore are respectively replaced by the equations (6), (7) and (8) hereinafter:

$$VDD_CPU_FB=VDD_CPU_SENSE+VDAC \quad (6)$$

$$VDD_CPU_SENSE=(VRef(R1+R2)/R1)-VDAC \quad (7)$$

$$VDD_CPU_SENSE=VDD_CPU_max-VDAC \quad (8)$$

Outside of the power-up phase, in other words during the steady-state power supply phase, the regulation means **2** form the feedback loop BCL in FIG. 7 and the regulation sequence is as follows.

When there is a request for a change of voltage from the power supply (for example a new point of operation DVFS), the control means **101** determine a new desired regulated power supply voltage.

The block **101** therefore sends the setpoint signal SC corresponding to this new desired regulated power supply voltage to the control block **111** which generates the setpoint word MNC in such a manner that the offset signal VDAC satisfies the equation (7) hereinbefore.

The digital-analog converter **110** carries out this conversion during a certain period of time.

The signal VDAC is delivered to the adder **112** which delivers at its output the negative feedback voltage VDD_CPU_FB which satisfies the equation (6) hereinbefore.

The regulation means **2** then regulate the voltage at the output S20 in such a manner that the regulated voltage VDD_CPU reaches the new desired regulated power supply voltage VDD_CPU_SENSE.

Here again, the new desired regulated voltage thus obtained VDD_CPU_SENSE then becomes the effective supply voltage present on the power grid **100** of the module **10**.

In an analogous manner to what has been explained with reference to the embodiment in FIG. 1, the transition between the sending of the setpoint signal SC and the obtaining of the new desired regulated power supply voltage is here again very fast, typically of the order of a few microseconds.

Here again, if it is not desired to impose particular design constraints and to allow the establishment of the various power supply voltages of the device in any given order, during the power-up phase, operating the regulation means **2** in open loop mode should be avoided.

In this embodiment, this protection is obtained by closing the switch **1124** in the power-up phase so as to shunt the adder **112** and to deliver the voltage VDD_CPU_SENSE directly to the setpoint output S1.

By analogy to what has been written with reference to the preceding embodiment, during the power up until the voltage adaptation circuit **11** is operational, the regulated power supply voltage delivered to the output **S20** is given by the formula (9) hereinbelow:

$$VDD_CPU_pu=(R1+R2)Vref/R1 \quad (9)$$

The sequence of operations of the power-up phase is analogous to that described with reference to FIG. **4**, the regulation being applied according to the temporary loop BCLS in FIG. **8**.

More precisely, the voltage VDD_CPU_pu satisfies the equation (9) hereinabove. When all the regulators of the device are operational and the reset pin of the system-on-a-chip is disabled, the boot sequence for the system-on-a-chip can commence and reset the voltage adaptation circuit **11** by sending the setpoint signal **SC** corresponding to a desired regulated power supply voltage.

The control block **111** then opens the switch **1124** which renders the adder **112** operational.

The closed-loop regulation sequence illustrated in FIG. **7** can then be applied as described hereinbefore.

Reference is now made more particularly to FIGS. **9** to **11** in order to illustrate a third embodiment of the device.

As illustrated in FIG. **9**, this third embodiment differs from the second embodiment of FIG. **5** by the fact that the voltage adaptation circuit **11** furthermore comprises auto-power supply means for this circuit.

Furthermore the others modules **12** of the system-on-a-chip are powered by the voltage VDD_SOC delivered by the regulator **3**.

The auto-power supply means here comprise a voltage step-up switch-mode converter **114** powered by the power supply voltage VDD_CPU present on the input **E1**.

This converter then increases the voltage in order to deliver the analog voltage $VDDA$.

Furthermore, the voltage adaptation circuit comprises a clock signal generator **115** which is active during the power-up phase of the device and which supplies a clock signal to the control block **111** at least until the clock signal of the system-on-a-chip is available.

Here again, during the power-up phase, the adder **112** is "shunted" by the switch **1124** (FIG. **6**).

The regulation is carried out according to the temporary loop BCLS in FIG. **10**. The initialization sequence is analogous to that described with reference to the preceding embodiment with the following differences.

As soon as the voltage VDD_CPU appears, the converter **114** starts up and the voltage $VDDA$ is established which allows the adder **112**, the digital-analog converter **110**, the control block **111** and the generator **115** to be powered.

The clock generator **115** starts up and is allowed to stabilize. The signal known by those skilled in the art under the acronym POR (Power On Reset) is disabled.

The state machine of the control block **111** then resets the digital-analog converter **110** and fixes its output voltage at a predefined value, for example 50% of the voltage excursion.

Furthermore, the control block **111** opens the switch **1124**.

From now on, the voltage regulation can operate according to the loop BCL in FIG. **11** in a manner analogous to what has been described hereinbefore.

The invention is not limited to the embodiments and their implementation which have just been described but encompasses all their variants.

Thus, various types of voltages regulators are possible. Similarly, various implementations (differential, common mode, etc.) are possible for the voltage adaptation circuit **11**.

The invention claimed is:

1. A method for powering a module incorporated within a system-on-a-chip, comprising:

in a steady-state power supply phase:

supplying to the module a regulated power supply voltage obtained from a feedback control loop receiving a main power supply voltage and a negative feedback voltage, and

generating the negative feedback voltage inside the system-on-a-chip starting from an effective supply voltage of the module and from a setpoint signal corresponding to a desired regulated power supply voltage, and

in a power-up supply phase:

generating the negative feedback voltage by blocking influence of the setpoint signal on the negative feedback voltage while simultaneously avoiding an open loop mode of operation for supplying the power supply voltage.

2. The method according to claim **1**, wherein generating the negative feedback voltage comprises:

converting a setpoint digital word taken from the setpoint signal into a voltage offset analog signal; and

summing of the voltage offset analog signal and the effective supply voltage.

3. The method according to claim **1**, wherein generating the negative feedback voltage comprises:

converting a setpoint digital word taken from the setpoint signal into a voltage offset analog signal; and

subtracting the voltage offset analog signal from the effective supply voltage.

4. The method according to claim **1**,

wherein blocking influence comprises: placing into high impedance a setpoint output of the system-on-a-chip configured to deliver the negative feedback voltage, and

wherein avoiding the open loop mode comprises: establishing a temporary feedback control loop using a resistor connected between a power supply input of the system-on-a-chip receiving the regulated power supply voltage and the setpoint output.

5. The method according to claim **4**, further comprising placing the setpoint output into low impedance during the transition between the power-up phase and the steady-state power supply phase so as to re-establish the feedback control loop going via the system-on-a-chip.

6. The method according to claim **1**, wherein blocking influence and avoiding the open loop mode comprises: directly delivering the effective supply voltage to a setpoint output of the system-on-a-chip configured to deliver the negative feedback voltage.

7. An electronic device, comprising:

a system-on-a-chip, comprising:

a power supply input configured to receive a regulated power supply voltage,

a circuit module configured to be powered by the regulated power supply voltage,

a controller configured to generate a setpoint signal corresponding to a desired regulated power supply voltage for the circuit module,

a voltage adaptation circuit configured to generate a negative feedback voltage starting from an effective supply voltage of the module and from the setpoint signal, and

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- a setpoint output configured to deliver the negative feedback voltage, a voltage regulator, comprising:
 a regulation output coupled to the power supply input,
 a negative feedback input coupled to the setpoint output, 5
 wherein the voltage regulator is configured to deliver the regulated power supply voltage to the regulation output starting from a main power supply voltage and from the negative feedback voltage; 10
 and
 a protection circuit operating during a power-up phase to block influence of the setpoint signal on the negative feedback voltage while simultaneously avoiding an open loop mode of operation for the voltage regulator to supply the power supply voltage. 15
- 8.** The device according to claim 7, wherein the voltage regulator is a switch-mode regulator comprising:
 a switching circuit connected between a main input for receiving the main power supply voltage and the regulation output, and 20
 a comparator generating a control signal for controlling the switching circuit using a comparator having a first comparator input designed to be connected to a reference voltage and a second comparator input coupled to the negative feedback input via a divider circuit. 25
- 9.** The device according to claim 7, wherein the voltage adaptation circuit comprises:
 a digital-analog converter configured to deliver, in the presence of a setpoint digital word taken from the setpoint signal, a voltage offset analog signal; and 30
 an adder configured to add the voltage offset analog signal and the effective supply voltage to generate the negative feedback voltage.
- 10.** The device according to claim 9, wherein the protection circuit comprises a controllable switch configured for shunting the adder in such a manner as to deliver the effective supply voltage to the setpoint output as long as the voltage adaptation circuit is not powered. 35
- 11.** The device according to claim 7, wherein the voltage adaptation circuit comprises: 40
 a digital-analog converter configured to deliver, in the presence of a setpoint digital word taken from the setpoint signal, a voltage offset analog signal; and
 a subtractor configured to subtract the voltage offset analog signal from the effective supply voltage to generate the negative feedback voltage. 45
- 12.** The device according to claim 11, wherein the protection circuit comprises:
 a resistor connected between the power supply input and the setpoint output; and 50
 a controllable switch connected between the output of the subtractor and the setpoint output,
 wherein the controllable switch is controlled to be in an open state as long as the voltage adaptation circuit is not powered, and 55
 wherein the controllable switch is controlled to be in a closed state when the voltage adaptation circuit is powered.
- 13.** The device according to claim 7, further comprising an auto-power supply for the voltage adaptation circuit. 60
- 14.** A device, comprising:
 a voltage regulator circuit having a regulated voltage output and an input configured to receive a feedback control voltage, the voltage regulator circuit generating a regulated voltage at the regulated voltage output in response to the feedback control voltage; 65

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- an application circuit powered by the regulated voltage, said application circuit including:
 a processor executing an application configured to output a setpoint signal indicative of a desired supply voltage for the processor;
 a sense circuit configured to sense an actual supply voltage for the processor;
 a conversion circuit configured to generate said feedback control voltage in response to the sensed actual supply voltage and the setpoint signal; and
 a protection circuit operating during a power-up phase to block influence of the setpoint signal on the negative feedback voltage while simultaneously avoiding an open loop mode of operation for the voltage regulator circuit to generate the regulated voltage.
- 15.** The device of claim 14, wherein said conversion circuit comprises:
 an analog to digital converter configured to convert the setpoint signal to an offset voltage; and
 a subtraction circuit configured to subtract the offset voltage from the sensed actual supply voltage to generate said feedback control voltage.
- 16.** The device of claim 14, wherein said conversion circuit comprises:
 an analog to digital converter configured to convert the setpoint signal to an offset voltage; and
 an addition circuit configured to add the offset voltage to the sensed actual supply voltage to generate said feedback control voltage.
- 17.** The device of claim 14, wherein the voltage regulator circuit comprises:
 a comparator configured to compare a voltage derived from the feedback control voltage to a reference voltage;
 control logic configured to generate a switch control signal from an output of the comparator; and
 a switch coupled between a supply source and the regulated voltage output, said switch selectively actuated in response to said switch control signal.
- 18.** The device of claim 14, further comprising a resistor coupled between the regulated voltage output and the input configured to receive the feedback control voltage.
- 19.** A method for powering a module incorporated within a system-on-a-chip, comprising, in a steady-state power supply phase:
 supplying to the module a regulated power supply voltage obtained from a feedback control loop receiving a main power supply voltage and a negative feedback voltage, and
 generating the negative feedback voltage inside the system-on-a-chip starting from an effective supply voltage of the module and from a setpoint signal corresponding to a desired regulated power supply voltage,
 wherein generating the negative feedback voltage comprises:
 converting a setpoint digital word taken from the setpoint signal into a voltage offset analog signal; and
 subtracting the voltage offset analog signal from the effective supply voltage.
- 20.** The method according to claim 19, further comprising, in a power-up phase of the system-on-a-chip, avoiding making the regulation operate in open loop mode.
- 21.** The method according to claim 20, wherein avoiding comprises:

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placing into high impedance a setpoint output of the system-on-a-chip configured to deliver the negative feedback voltage in steady-state mode, and establishing a temporary feedback control loop using a resistor connected between a power supply input of the system-on-a-chip receiving the regulated power supply voltage and the setpoint output.

22. The method according to claim 21, further comprising placing the setpoint output into low impedance during the transition between the power-up phase and the steady-state power supply phase so as to re-establish the feedback control loop going via the system-on-a-chip.

23. The method according to claim 20, further comprising, in the power-up phase, directly delivering the effective supply voltage to a setpoint output of the system-on-a-chip configured to deliver the negative feedback voltage in steady-state mode.

24. An electronic device, comprising:
a system-on-a-chip, comprising:

- a power supply input configured to receive a regulated power supply voltage,
- a circuit module configured to be powered by the regulated power supply voltage,
- a controller configured to generate a setpoint signal corresponding to a desired regulated power supply voltage for the circuit module,
- a voltage adaptation circuit configured to generate a negative feedback voltage starting from an effective supply voltage of the module and from the setpoint signal, and
- a setpoint output configured to deliver the negative feedback voltage, a voltage regulator, comprising:
 - a regulation output coupled to the power supply input, and
 - a negative feedback input coupled to the setpoint output,
 wherein the voltage regulator is configured to deliver the regulated power supply voltage to the regulation output starting from a main power supply voltage and from the negative feedback voltage; and

wherein the voltage adaptation circuit comprises:

- a digital-analog converter configured to deliver, in the presence of a setpoint digital word taken from the setpoint signal, a voltage offset analog signal; and
- a subtractor configured to subtract the voltage offset analog signal from the effective supply voltage to generate the negative feedback voltage.

25. The device according to claim 24, wherein the voltage regulator is a switch-mode regulator comprising:

- a switching circuit connected between a main input for receiving the main power supply voltage and the regulation output, and
- a comparator generating a control signal for controlling the switching circuit using a comparator having a first comparator input designed to be connected to a refer-

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ence voltage and a second comparator input coupled to the negative feedback input via a divider circuit.

26. The device according to claim 24, further comprising a protection circuit configured to avoid, when the system-on-a-chip is powered up, an operation of the voltage regulator in an open loop mode.

27. The device according to claim 26, wherein the protection circuit comprises:

- a resistor connected between the power supply input and the setpoint output; and
- a controllable switch connected between the output of the subtractor and the setpoint output, wherein the controllable switch is controlled to be in an open state as long as the voltage adaptation circuit is not powered, and wherein the controllable switch is controlled to be in a closed state when the voltage adaptation circuit is powered.

28. The device according to claim 24, further comprising an auto-power supply for the voltage adaptation circuit.

29. A device, comprising:

- a voltage regulator circuit having a regulated voltage output and an input configured to receive a feedback control voltage, the voltage regulator circuit generating a regulated voltage at the regulated voltage output in response to the feedback control voltage;
- an application circuit powered by the regulated voltage, said application circuit including:
 - a processor executing an application configured to output a setpoint signal indicative of a desired supply voltage for the processor;
 - a sense circuit configured to sense an actual supply voltage for the processor; and
 - a conversion circuit configured to generate said feedback control voltage in response to the sensed actual supply voltage and the setpoint signal;
 wherein said conversion circuit comprises:
 - an analog to digital converter configured to convert the setpoint signal to an offset voltage; and
 - a subtraction circuit configured to subtract the offset voltage from the sensed actual supply voltage to generate said feedback control voltage.

30. The device of claim 29, wherein the voltage regulator circuit comprises:

- a comparator configured to compare a voltage derived from the feedback control voltage to a reference voltage;
- control logic configured to generate a switch control signal from an output of the comparator; and
- a switch coupled between a supply source and the regulated voltage output, said switch selectively actuated in response to said switch control signal.

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